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AUTO ID PARADIGM SHIFTS FROM INTERNET OF THINGS TO UNIQUE IDENTIFICATION OF INDIVIDUAL DECISIONS IN SYSTEM OF SYSTEMS

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Abstract

Return on investment (ROI) from radio frequency (RF) based tools of identification may increase with the diffusion of frequency agnostic modes of radio frequency identification (RFID), such as, ultrawideband (UWB). Similarly, fixed frequency readers may be replaced with interrogators that can operate in any frequency, such as software defined radio (SDR). Identification of objects provides data that may not be useful unless the process of data acquisition is further linked to systems where the data can be analysed and useful information extracted. This evolution remains incomplete because data about objects is only a small segment of necessary information. Global businesses and systems, such as healthcare, demand much more than object data. Often processes and plans as well as prior decisions are taken into account when deciding on a future course of action or the next step. Current practice of auto id, although useful, remains only a small part of what is necessary for identification of information in complex system of systems. Identification, therefore, must encompass systems interoperability as well as the ability to enumerate both tangible and intangible elements that contribute to decisions. The unique "address" must be preserved during information exchange and decision support between systems to ensure interoperability.

Keywords

Auto ID, RFID, EPC, IPv6, Information Age, Sensors, UWB, SDR, Decision Systems, Interoperability, Systems Age

Background

Nature's gift of the radio spectrum is subjected by humans in government and industry to dissection and control. It has resulted in a globally fractured state of communication when using radio frequency. Redundant investments are necessary to move between "restricted" frequencies and the process has turned into a sham with spectrum auctions pioneered by several affluent nations for commercial purposes. Regulating the use of radio spectrum has distinct advantages (defense, emergency, medicine) but the current quagmire may overshadow the benefits.

During WWII, the discovery of RADAR unleashed the potential of radio frequency to identify objects. Almost half century later, in 1987, Norway pioneered the first public use of RFID. Transponders were attached to vehicles to facilitate toll collection. The tag operated at a fixed frequency and the frequency used was (and is) irrelevant to the function of the static process. Globalization has stimulated movement of objects across diverse geographies. Now, it is imperative that we determine the status of supply and demand of goods. Global visibility of goods movement may require automatic identification of vast number of objects (in trillions). This necessity may be answered in part by harnessing the internet to catalyse the re-birth of the use of RFID. Thus internet-based object identification was rejuvenated at the hands of the Auto ID Center at MIT beginning around 1999.

Opportunity: Potential to Eliminate Frequency Heterogeneity

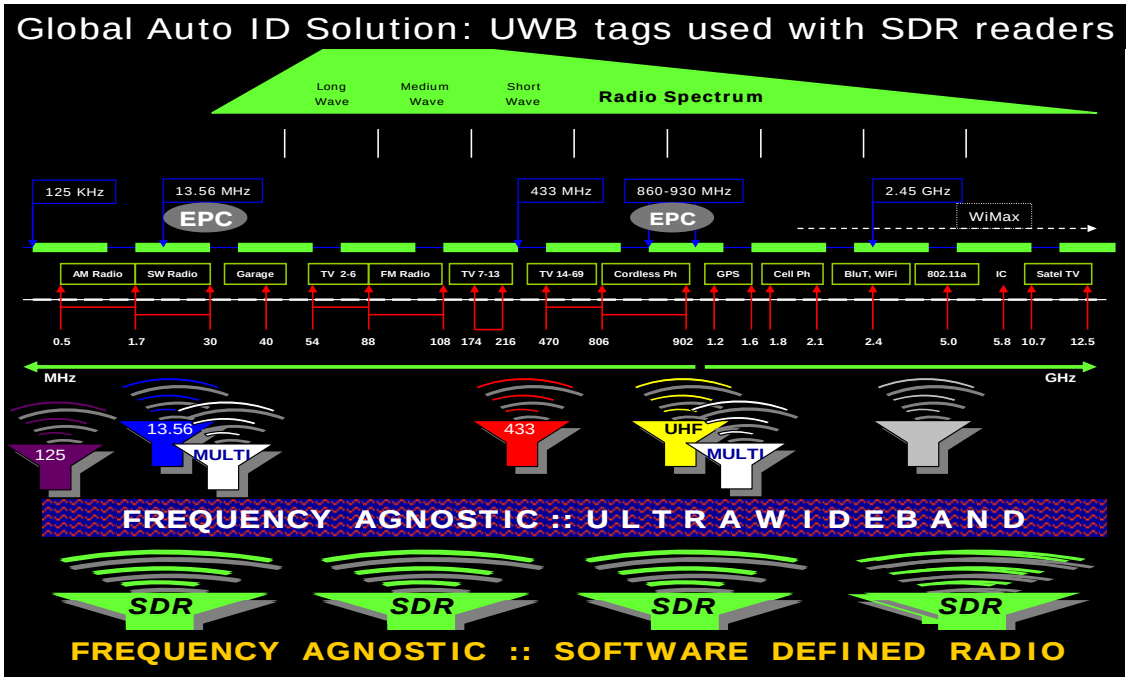
The surge in the popularity of RFID ignored the limiting fact that most RFID tags operate in a fixed frequency and readers must also operate in the same fixed frequencies. Add to this mix the different spectrum usage specific to geographies plus preferences for standards for data capture, for example, EPC (electronic product code). What emerges is an interoperability nightmare from multitude of tags, readers, investment in multiple infrastructures and the conflicting complexity of multiple "standards" in a plethora of proprietary systems.

The problems with automatic identification should not suggest that automatic identification has lost its appeal. Auto id and concomitant location of object are important data elements whose value is growing exponentially in business supply chains. It is even more critical for security of global trade, for example, in multi-national logistics operations such as goods transport between Asia and Europe on the Trans-Siberian Railroad. In such systems, fixed frequency RFID tools may be a hindrance to operations and are liable to create gaps in (data) transparency due to lack of systems interoperability. This article highlights select technologies that may reduce frequency heterogeneity for some applications. However, this is not a panacea that calls for discontinuing use of fixed frequency standards.

Frequency Agnostic Technologies: Ultrawideband (UWB) and Software Defined Radio (SDR)

In use since 1962, UWB is essentially RFID but it can communicate over a broad (hence, *ultra wide*) spectrum (band) rather than fixed ranges that are common in typical RFID [1]. The physics of transmission is different and enables UWB to use short (picosecond) bursts of frequency over the broad spectrum (hence, difficult to de-code). This is a frequency agnostic tag that is currently used in several operations as an active tag (battery) but may be transformed into a passive format.

Invented in 1991, SDR [2] is essentially a radio that can operate (receive and transmit) over a broad spectrum (think, car radio). Hence, it can interrogate tags and receive signals from UWB tags. The incoming frequency is selected using the software embedded in these devices (hence, software defined radio) and is immune to frequency heterogeneity and functions in a manner that is frequency agnostic. Combination of frequency agnostic UWB tags and SDR readers may increase the diffusion of auto-id tools and enhance systemic implementation, globally.



Standards may not always deliver a standard solution

Based on the current thinking that track and trace technologies must identify objects, it is necessary to capture the id of objects in some alphanumeric format. Thus, current tools are drowning in a multiplicity of so-called standards. Problems encountered due to globalisation result from the unlimited movement of objects (inanimate and animate objects such as humans) in domains where standards are not useful, practised, accepted, adopted, implemented or enforced. Systems often cannot communicate due to lack of interoperability. Thus, we have an embarrassment of riches with respect to data while we continue in abject poverty of information due to lack of interoperability in this systems age. The latter has, erroneously, promoted even more calls for standards and even larger consortiums are being formed to muscle global adoption (acceptance). The success of this approach is open to question by the dubious success of Wal*Mart-esque efforts to usher in global network visibility that auto id was expected to deliver.

The lesson from the age of introduction of the electric dynamo [3] is ignored by the current drive to pursue quick fixes including the pursuit of *one* elusive standard. Gobal leverage may be used to promote interoperability between select partially adopted standards in a way that systems can interface seamlessly through translational mechanisms (obvious analogies from human language). This approach is standards agnostic yet could remain multi-standard compliant. Sensors and RF technologies are enabling tools that detect, monitor or identify but may not add real value unless the process or system generates *decisionable information*.

Ultrawideband (UWB)

Most RFID types (125KHz, 13.56MHz, 433MHz, 868-915MHz) possess a spatial capacity [4] of 1 kbpspm^2 (kilobits per second per meter squared). Spatial capacity focuses not only on bit rates for data transfer but on bit rates available in confined spaces (grocery stores) defined by short transmission ranges. Measured in bits per second per square meter, spatial capacity is a gauge of "data intensity" that is analogous to lumens per square meter that determines the illumination intensity of a light source. Growing demand for greater wireless data capacity and crowding of regulated radio frequency (approved for industry, science and medical purposes or ISM spectra) will increasingly favour systems (spectrum) that offers appreciable bit rates and will function despite noise, multipath interference and corruption when concentrated in small physical areas (stores, warehouses, hospitals). Will spatial capacity limitations clog the 'interrogation' system if item level tags are used? Some are exploring BlueTooth with spatial capacity of 30 kbpspm^2 while asset management may use 802.11a protocol (5.15-5.35 GHz) with spatial capacity of 55 kbpspm^2 (for example, metal spare parts in airline repair shops, for example, Lufthansa Technik).

Quite a few companies are exploring UWB since its appearance on the scene in 1962 (it may have been identified as "spark-gap" technology by Marconi in 1894). UWB spans several gigahertz of spectrum at very low power levels below the noise floor of existing signaling environment. The spatial capacity of UWB is 1000 kbpspm^2 or 1000-fold more than 802.11b (WiFi). Conventional narrow band technology (802.11b, BlueTooth, 802.11a) rely on a base "carrier" wave that is modulated to embody a coded bit stream. Carrier waves are modified to incorporate digital data through amplitude, frequency or phase modulation. These mechanisms are susceptible to interference and the coded bit stream (for example, EPC) may be decoded or intercepted, posing data security issues. UWB wireless technology uses no underlying carrier wave but modulate individual pulses either as bipolar or amplitude or pulse-position modulation (sends identical pulses but alters transmission timing). UWB offers pulse time of 300 picoseconds and covers a broad bandwidth extending to several gigahertz. UWB operates in picosecond bursts and power requirements are drastically lower (200 mW) compared to 802.11b (500 mW) or 802.11a (2000 mW). Data rate for UWB is 0.1 – 1.0 gbps^2 (gigabits per second square) compared to 0.006 gbps^2 for 802.11b.

Sony and Intel, among others, are leading this research for wireless transmission of data, video, networked games, toys and appliances. Today we have robotic vacuum cleaners and lawn mowers that clean the living room or the manicured garden without ever touching the sofa or grazing by the rose bush. Universal appeal for UWB is latent in its capability to offer a global standard. Without FCC-like country-specific restrictions, an old technology like UWB still remains virgin for many possible applications and may be the only global wireless communication medium that may claim, someday, a truly global standard.

After 2001 September 11, UWB transmitters (similar to RFID readers) were mounted on robots for search missions at the World Trade Center since UWB penetrates metal (cans, spare parts) or concrete (buildings and warehouses). On 14 February 2002, the FCC ultimately gave qualified approval to use UWB [5] in the range >960 MHz, 3.1-10.6 GHz and 22-29 GHz. Limiting power also limits UWB efficacy and spectrum.

UWB-RFID active transponders are not prohibitive in cost while transmitters may be even cheaper than 802.11b RFID readers because they do not need many analog components to fix, send and receive specific frequencies. The combination of UWB plus narrowband technology to produce a passive UWB transponder may be a reality by combining UWB communication with narrowband RFID tag [6]. Combining a narrowband receiver and a wideband transmitter in the tag optimizes collecting RF energy on the receive channel combined with ultra low power on transmit channel. At the MAC layer, optimized conflict resolution algorithms allow multiple tags to communicate efficiently and effectively with the reader. Due to this algorithm, the channel is used efficiently by taking advantage of the principle of orthogonal frequency division multiplexing (OFDM). This results in an increased effective bandwidth that allows more tags to communicate with the reader. Similar use of OFDM to enhance fixed frequency RFID readers may be useful, too. Thus, utilization of narrow band downlink and wide band uplink communication enables wholly (passive) or partially battery-less tag designs to be manufactured at low cost. UWB communication is resilient to selective RF absorption, since the data can be recovered by the reader by relying on the message content in the 'not-absorbed' frequency bands. Due to the very broad frequency content of the transmitted UWB impulse, it is extremely resilient to path fading and enables readers to determine location of tags. Thus, UWB not only identifies, it can also locate (for example, movement of objects in a warehouse, storage organization). Unlike traditional passive RFID tags, passive UWB tags use accumulated power to transmit UWB impulses to the reader. Tags are re-writeable and can be programmed to have 64, 96, or 128 bits [7].

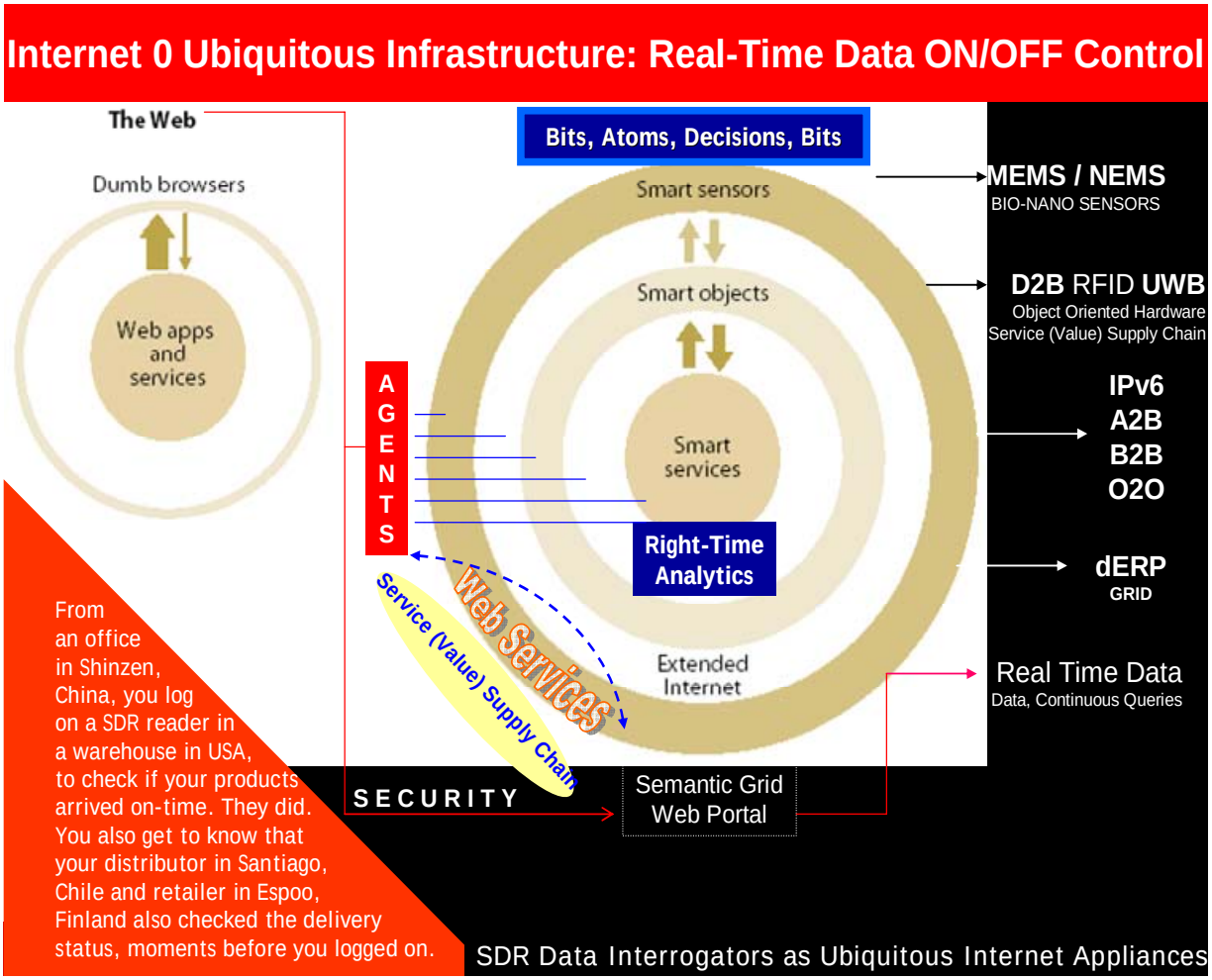
Despite the clear advantages of passive UWB RFID tags, in general, the dispute in the field stems from claims that UWB transmission may interfere with spectrum used by cell phones and air traffic control. FCC is investigating but it is poised to open up even more of spectrum for UWB commercial applications. Without the burden of license fees for spectrum usage, the commercial floodgates for UWB usage may be unstoppable much to the chagrin of the telecom industry. MSSI is charting new territories and PulseLink has shown that SDR readers work with UWB chips.

Software Defined Radio (SDR)

The current thinking to use 'readers' specific to one or more RF modes may not be a feasible approach for the infrastructure necessary for object identification to become pervasive. Heterodyne readers that can read MHF (13.56MHz) and UHF (902-956MHz) tags cost about $5000. Now consider, commonly used frequencies, RFID vs UWB, passive vs active, multiple standards (EPC, GTAG) and regional regulations (RF spectrum, emitted radiated power). Taken together, it spawns several types of transponders and to read multiple tags, a variety of readers are necessary. Multi-frequency tags and readers may not adequately address the problem or reduce infrastructure cost.

In the current model, businesses dealing with objects from global partners must possess the infrastructure (several types of readers) compatible to read a plethora of tags. Readers or tag interrogators, in future, must be as ubiquitous as a *civil engineering infrastructure* similar to electrical outlets, evolving to form the internet of devices (Interdev). Software will be part of the infrastructure to enable pervasive data acquisition as well as dissemination (transmission). Data and information sharing may be a reality if security enabled open source software is deployed as infrastructure that responds to global interoperability. Control, security, updates and hardware improvements may be delivered via this ubiquitous systemic software infrastructure. It is this scenario that is outlined in the illustration (below) where the reader in a warehouse is always 'on' but the ability to read certain objects (or not) is controlled through the software layer by the authorized user and the authorizations allowed by the principal user. The 'views' of the contents of the warehouse is limited to objects that the user can 'read' by virtue of the preamble that must be exchanged and validated between the reader and tag (similar to architecture embedded in EPC).

SDR is a solution at hand to deliver part of this ubiquitous infrastructure in a manner that will remain transponder hardware agnostic with all modulations effected through the SDR operating systems (OS). This view, that of, using SDR hardware (in some form) as ubiquitous RFID interrogators (in a refrigerator or in a warehouse) is the proposal based on the current understanding [8] of software radio (SWR). In 1991, the term "software defined radio" was coined to describe radio devices implemented in software and running on generic hardware. Because SDR is linked to global mobile telephony, an area of convergence between SWR infrastructure for real-time data and *delivery of real-time data as a service*, may evolve as a robust business for telecom providers [9]. A potential *modus operandi* using internet protocol version 6 (IPv6) and a plausible revenue model is discussed in an earlier paper [7].



Paradigm Shift: Identification of Information

Tools and technologies, discussed above, add significant costs to any operation. The justification of the investment necessary to connect bits to atoms has taken on a special significance in recent years but it has been growing since the demise of the Cold War and continues to increase with the robust economic growth of BRIC nations (Brazil, Russia, India, China). The internet has facilitated the connectivity of the bits (data) that enables creation of virtual maps of atoms (things). This 20th Century perspective to map the Physical World evolved in parallel with the ascent of the Information Age. Generation of raw data accelerated exponentially, in part, due to the plethora of tools. Yet productivity gains remain incremental. The necessity to identify objects began with the barcode in 1975 but soon created a surfeit of numbering systems, including the "e-barcode" or EPC (electronic product code).

As its name implies, EPC and other alphanumeric identification systems are associated with products, that is, finite objects or actual things. In the real world, raw data about an object or group of objects, alone, may be insufficient for any *decisionable* information or less helpful for decision support systems or decision making process aided by humans. Data about atoms (things) also include chemically synthesized molecules, for example, small molecules designed by organic chemists for drug assays in pharmaceutical companies. However, standards such as EPC focus on products or objects since the context of the barcode and EPC originates from the retail industry supply chain. Object data (atoms and products) must be combined with process (intangible in terms of atoms but bit-friendly) and logic must be applied to extract information, which, may be subjected to further analysis [11]. Hence, data is ***not*** information. The Information Age, as appropriate it may have been in the last century, may no longer be a useful description of the present era since information, *per se*, is increasingly toothless.

Information, to be of value, must help the decision making process, either through decision support systems or human-aided chaos. Useful information or decisionable information may help transactions, either in business or healthcare or in a variety of other systems. Decisionable information in one domain, for example, purchasing, may not be an end in itself. It may be necessary to couple that information with another, equally valuable, decisionable information, for example, in manufacturing. Information from the purchasing system and manufacturing system, when taken together and if the systems are interoperable, may offer guidance for buyers to initiate requisition for raw materials in the ordering system. It is evident that systems must be connected for valuable information to be useful in the transactional space of interoperable decision systems. This spells the end of the Information Age.

Systems Age aptly describes the growing necessity to connect information from a variety of sub-systems that may be related by the function being executed in order to deliver value. The appreciation of the significance of *related* information and the system of systems [SOS] interoperability approach is a theme that is central to future innovation in identification from the perspective of creating intelligent decision systems [10]. The broad spectrum of applicability of this fundamental principle may be appreciated through the vision of *relativistic* information [7] that is important to business operations, information services, healthcare, biomedical sciences and research, including the core disciplines that drive industrial growth. Globalization has catapulted Systems Age to where the monolithic enterprise resource planning (ERP) systems and silo approaches must adapt or die.

Identification of objects in any global operation or within a system of systems framework (for example, healthcare), offers limited functionality. Identification must rise to a higher plane to address *identity* of information that includes identification, which may be similar. Information flow of tangible and intangible elements are equally crucial to aid decision support in hierarchies of synergistic systems. For example, 2 individuals who are both named Mary Smith may have identical blood glucose levels (120 milligrams per deciliter). Identification of Mary Smith may be uniquely achieved through a social security number (SSN), but how to *number* 120, which is identical in both instances? The combination of SSN with 120 creates an *unique identity* that includes identification of an object (human being) but provides a higher plane of information when taken together with a non-physical or intangible piece of raw data.

The volume of data and volume of related nature of data and information is vast. High volume data has distinct advantages [12] but the resulting decisions may be distributed over several systems. Interoperability between systems and success in local, as well as global, decision making, demand management of information that is identifiable, yet remains platform agnostic but multi-standards compliant [13]. Identification of information must address the need for *unique identification of decisions* that may involve hierarchical layers of data, information and decision, each with its unique identification, in local or geographically dispersed, system of systems.

This paradigm shift offers the potential to create new products and services to drive future economic growth. The convergence of tools, technologies, concepts and disciplines necessary to transform this vision into reality demands cross-pollination of global institutions to stimulate collective innovation in addition to world-wide academic-industry partnerships and core research programmes with a critical mass of faculty and students capable of addressing the challenges that are known and the known unknowns, not to mention, the unknown unknowns.

Temporary Conclusion

Globalization demands innovation in standards agnostic information identification because identification of physical objects is insufficient for decision support. The myopic view of auto id and numbering of objects is justifiable for an IT company if it must focus on delivery of dividends for shareholders in the next quarter. But, the haste to reap the mythical mirage of "low hanging fruits" may be detrimental to the informed vision of sustainable future economic growth. Guiding the latter is the responsibility of academic foresight and academia, as the purveyors of civilization.

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